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MAPS AND NAVIGATION METHODS.

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MAPS AND NAVIGATION METHODS.*

By

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Before undertaking any voyage, however short, the aerial navigator provides himself with the necessary maps. This is an easy matter in our country, where there is a wide choice among the various maps published by the Géographique Section of the Army, the Department of the Interior and the Aero Club.

When it is a question of a trip into a foreign country, the case is no longer the same. In some countries the only existing maps are incorrect or poorly edited, while in others they are comparable with ours, but French navigators, not being accustomed to their scales, nor to their colors, nor to their special manner of presentation, do not find them convenient. Reciprocally, foreigners experience the same inconvenience in using our maps. The most commonly used map is drawn on the scale of 1 : 200,000. This gives the most details of interest to the aviator, without taking too much paper. The 1 : 1,000,000 scale is useful for long voyages. It is always best to carry the corresponding maps on the 1 : 200,000 scale, for the aerial navigator sometimes has occasion to identify details not shown on the 1 : 1,000,000 map.

These two maps are not specially made for aviators. It seems therefore that the solution of the problem has progressed hardly any since Mr. Lallemand, member of the Institute, asked for the creation of aviation maps. This delay is explained by the fact

* From "Premier Congrès International de la Navigation Aérienne," pp. 150-155, Paris, November, 1921.

that during the war the existing maps (1 : 300,000 of the Geographic Section of the Army, and 1 : 136,720 of the "Ordonnance Survey") were satisfactory to the aviators of the allies, who flew in restricted sectors and seldom made long voyages.

Now the requirements of civil aeronautics, the chief object of which is to make voyages, are different and depend on aviation maps. This fact did not escape the attention of the experts who drew up the international agreement of October 13, 1919, containing regulations for aerial navigation. Annex F, of this agreement or convention, made provision for various international aviation maps, which the contracting countries will publish within a few years. Already three of the most enterprising nations have agreed on the details of execution, as we shall see further along.

Anyway, it is not out of place to call attention to the scope of the task undertaken, as well as to the value of the preliminary work accomplished since 1919. If the aviators, who are wanting aviation maps worthy of the name, had any idea of the work accomplished, their very natural impatience would be less prompt to manifest itself.

Under the respective designations of normal maps and general maps, the convention established two types of international aviation maps. In principle, they must be made according to the rules adopted for the 1 : 1,000,000 map of the world, with the metric system of measurements. Each country, however, has the privilege to add its own units of measurement to the maps it publishes.

After discussion during the English-French-Belgian conferences of 1920 and 1921, the details of the conventional symbols were fixed. Since their exposition lies outside the scope of this article, we will confine ourselves to a general description of the two kinds of maps provided for.

General maps.— The general map is made according to Mercator's projection, one degree of longitude being represented by a length of three centimeters, which gives, in our latitude, an average scale of about 1 : 2,000,000. Each folio contains a complete number of the sections of the map of the world on the 1 : 1,000,000 scale, which is generally nine for latitudes below 60°, six and even three for higher latitudes. Each side of each sheet covers 1° in latitude by 2° in longitude. There is a common portion on adjacent sheets, which facilitates the passage from one sheet to the next.

The relief is indicated by hypsometric tints supplemented by altimetric figures and, where there is occasion for it, by a slight shading. This method of representing the relief is in conformity with the 1 : 1,000,000 map of the world. It enables the aviator to choose instantly, without risk, the altitude of safety, in case of poor visibility. Any representation of relief, accomplished simply by means of shading and altitude figures, does not offer this advantage, since the navigator must read all the altitudes of a region in order to determine the altitude of safety. He runs the risk of overlooking that of the summit, against which he is in danger of

crashing. The necessity of judging the altitude of the whole region led to the use of hypsometric colors for the general map. It is omitted on the normal maps, where each section bears on its margin the altitude of the highest point and of the lowest point in the region represented. The relief of the normal map is also shown by shading.

Lastly, general maps are only provided for continents. Aviation maps are not necessary, in fact, for the oceans, for which the aeronaut will use marine maps, based on Mercator's projection.

Normal maps.— These are published on the scale of 1 : 200,000. The kind of projection is not stipulated. This is because, on the one hand, the various projections differ but little on this scale and because, on the other hand, of the great advantage of being able to make use of much existing cartographic material.

Each section of the normal map embraces 1° in longitude and 1° in latitude. They will doubtless overlap one another by several kilometers. The relief is indicated by shading, supplemented by altimetric figures.

Miscellaneous maps.— The object of the convention was to create a set of identical aeronautic maps for the whole globe. Aside from these standard maps, the aerial navigator may use any others. Let us note, in passing, the 1 : 200,000 map of Capt. Hebrard and Lieut. Robbe, on which the roads stand out light against a dark background. The advantages of this method will be manifest, when night flights become common.

Maps are indispensable for the aviator. Their conception, however, depends on the methods employed in aerial navigation, which we will now endeavor to set forth.

"To navigate is to go from one point to another by the shortest and easiest route." This applies to both water and aircraft.

Aerial navigation, although freely accomplished in three dimensions (with certain restrictions in the vertical direction) is in all points comparable with maritime navigation. On the contrary, it is not comparable with the means of land transportation.

In fact, there are two methods of navigating an aircraft:

1. To fly with continuous reference to landmarks;*
2. To take a direct route by the compass, with only occasional reference to the ground for determining the position of the aircraft.

The former method, which is chronologically older, is still commonly employed. Although comprehensible in the beginnings of aviation, when only the pilot was on board and the voyages were of short duration, it is now an anachronism. To be compelled to follow a railway or a river is a loss of time. This method is, moreover, not very safe, for as soon as the pilot loses this "thread of Ariadne," he is lost. Errors have been frequent at cross-roads and junctions. Lastly, it is well to note the danger resulting

* Some authors make a distinction between following a continuous reference line (highway or railroad) and flying from one reference point to another by comparing the ground and the map. This is a distinction without a difference, since in cloudy weather they lead to the same result, flight near the ground.

from this practice. On a given aerial route, all the pilots would follow, in cloudy weather, exactly the same landmarks, thus creating great risk of collisions.

The second method, successfully employed on airplanes and airships by several crews, has stood the test for centuries in all navies. It is therefore no novelty, but merely an adaptation. By means of the compass, the pilot steers the aircraft in a constant direction with reference to the meridian. The path thus described is a loxodromic or rhumb line.

Hence, to steer by compass is to describe a loxodromic curve. The pilot only needs to choose the one which connects his starting point with his destination, and then to make sure from time to time that he has not departed from it and, lastly, to verify his speed.

The use of the compass renders it possible to follow the most direct route between two points and especially to lose sight of land without inconvenience, for a certain length of time. At any instant, the navigator can determine his position by "dead reckoning," with the aid of his absolute speed and the time elapsed.

The accuracy of this method depends on the pilot's skill in using his compass and on the exactness of his knowledge of the data employed, namely, the angle of the route followed and the absolute speed. The route angle is the angle formed with the meridian by the loxodromic trajectory described on the earth by the aircraft, which is steered with the aid of the compass.

As often as possible, this dead reckoning will be verified by

observations of terrestrial or celestial reference points, or other method (radiogoniometry, etc.).

Usually the wind causes the airplane to drift (uniformly, if the wind is regular). The angle between the axis of the aircraft, called the course, and the route actually followed is the angle of drift. The pilot must therefore endeavor to determine the course to be adopted so that the drift will cause him to follow the loxodromic line traced on the map. Practically, for holding the aircraft on this course, the pilot must determine opposite what graduation of the compass rose he must hold the reference mark which indicates the position of the axis of the airplane. The compass course is obtained by correcting the given course by the angle of "variation." This variation is the algebraic sum of the magnetic declination (angle formed, at any given place, between the geographic and magnetic meridians) and the deflection caused by the iron of the aircraft, which affects the magnetized compass needle. The declination is always exactly known. As to the deflection, an endeavor should be made to eliminate this once for all by "compensation," the explanation of which lies outside the scope of the present article. It is a very simple and practical operation. When properly executed, the residual deflection is very small (1° to 2°) and the directive force of the compass remains constant for different courses.

The only difficulty encountered in following a loxodromic or rhumb line is therefore the determination of the angle of drift.

By means of aerological soundings, this is easily determined before starting. The data for calculating the course then remain exact so long as the wind does not vary. If the wind is found to change, it becomes necessary to change the course steered or be driven off the true route. During the voyage, the navigator must employ one of the two following methods for determining the drift.

1. Determination, on the map, of two successive positions of the aircraft and of the exact route followed between these positions.

2. Instantaneous measurement of the drift by the observation of some point on the earth.

The first method utilizes what some call "navigation by observation," in which the navigator steers by calculation, which he rectifies by every observation made. He thus describes a series of loxodromic lines, each one starting from the last point observed.

The second method of measuring the drift necessitates a brief view of the earth, without its being necessary however to identify any given reference point. It consists in measuring the angle formed by the apparent motion of the reference point and the course of the aircraft. This measurement can be made, even when the reference point does not pass directly under the aircraft. The S.T.Ae. (Technical Section of Aeronautics) drift-meter and the Le Prieur "navigraph" are based on this principle. Moreover, the results are faithfully preserved, which constitutes a great advantage, since two successive drift measurements with different courses

give the magnitude and direction of the wind.

The absolute speed is measured: either by noting the time taken to traverse the distance between two observed points, which are shown on the map; or instantaneously by making measurements with reference to a single point, which does not need to be identified.

For utilizing the latter method, we may employ the navigraph, the S.T.Ae. drift-meter, or the Le Prieur "cinemograph."

In the S.T.Ae. drift-meter, there are two sighting wires, adjustable in altitude, which intercept a base of 500 km. on the ground. The navigator sights a reference point and measures with a chronograph the time of passage from one wire to the other. An abacus gives the absolute speed in km/hr.

In the Le Prieur cinemograph, the sighting is done with the aid of a slide carrying a stylus which traces a line on a paper moving vertically with a uniform speed. These combined uniform motions give a straight line, the inclination of which is a function of the altitude and of the speed. The errors due to changes in the trim of the aircraft are eliminated by the fact of the graphic inscription.

In the navigraph, the absolute speed is obtained by the automatic production of the triangle of velocities, of which the sides "air speed" and "wind" are known, as also the angle of drift.

Observation point.- This can be obtained by watching the ground. The navigator either identifies some reference point under him or determines his position with the aid of distant refer-

ence points.

When the ground is not visible, the observation point is found by observing the stars, according to methods similar to those employed at sea. Unfortunately, the mariner's sextant is not utilisable on aircraft and no other instrument has thus far afforded any practical solution of the problem. For want of an astronomical point, the aerial navigator can utilize radiogoniometry.

The preceding exposition shows that loxodromy is the basis of aerial navigation. The ideal map for aerial navigation is therefore the one on which all the loxodromes are represented by straight lines and their angles with the meridians. Only Mercator's projection will answer these requirements. Its use for general aeronautic maps is therefore fully justified.

As regards utilisable routes in aerial navigation, we have purposely omitted orthodromy (sailing on the arc of a great circle). The arc of a great circle is in fact the shortest way between any two points on the earth's surface and would therefore seem preferable to loxodromy. This advantage is however only theoretical, since for all points less than 1000 km (622 miles), the difference between the orthodrome and loxodrome is negligible (about 1/300). Now, the stops, the obligatory points for crossing frontiers, and natural obstacles impose an itinerary, whose sections rarely attain 1000 km. These sections are therefore loxodromes.

There remains the employment of orthodromy on very long trips. Here again flight on the arc of a great circle does not make good

its promises. If the points of departure and arrival are on the same parallel of latitude, the vertex or culminating point of the curve is near the pole and hence climatic considerations prevent the utilization of the most important part of the ideal curve. If the points of departure and arrival are almost on the same meridian or near the equator, the orthodrome and loxodrome differ but little. It should be noted, moreover, that the only method for describing a great circle consists in resolving it into a series of successive loxodromes of about 1000 km, which are followed by means of a compass.

The arc of a great circle therefore serves to determine an itinerary. There is no need of special maps for this purpose, since Mr. Favé, a member of the Institute, has invented a rapid and simple method of tracing the arc of a great circle on a Mercator map. The employment of the Favé abacus enables the aerial navigator to determine instantly and accurately the points through which an arc of a great circle passes by simply moving over the map a transparent sheet on which is traced a whole series of curves representing the projection of various great circles whose vertices are on any given meridian.

In conclusion, we may say that, on the one hand, the question of aeronautic maps is progressive and is following its normal course; while, on the other hand, the empirical methods of aerial navigation thus far employed are retrogressive, slow and dangerous and should be replaced by scientific methods of navigation, based on loxodromy and the use of the compass.

Translated by the National Advisory Committee for Aeronautics.